



Principal Investigator: Dr. Alexei Gruverman

Position Title: Professor

Department: Department of Physics and Astronomy

Email: agruverman2@unl.edu

Phone: 402-472-4788

Webpage: <https://physics.unl.edu/person/alexei-gruverman/>

Project Title.

Enhanced Energy Storage using Antiferroelectric Hafnia-Based Dielectrics

Abstract.

With the global push towards renewable energy, there is a growing demand for efficient, high-density, and scalable energy storage technologies. Traditional dielectric capacitors face limitations in energy density and scalability. Antiferroelectric (AFE) hafnia (HfO_2)-based materials have recently gained attention for their high dielectric breakdown strength, excellent scalability, compatibility with Si-based fabrication processes (CMOS), and field-induced phase transitions that enable high energy storage densities. However, critical challenges remain in understanding their AFE phase stability and enhancing the energy storage performance.

The goal of this project is to develop AFE hafnia thin films with enhanced recoverable energy density. This goal will be achieved by pursuing several inter-related objectives aimed at (1) identifying the processing conditions, chemical dopants and electrode materials optimal for stabilization of the AFE phase; (2) conducting accelerated energy performance testing of hafnia capacitors under varying temperatures, frequencies, and electric field strengths to optimize the field-induced phase transition characteristics; (3) boosting the energy storage capabilities by reducing the leakage currents, enhancing the retention characteristics and benchmarking their performance against commercial dielectric materials.

Employment of AFE hafnia will result in disruptive innovation in the energy storage technology due to the drastically enhanced energy density as well as hafnia compatibility with CMOS technology, which enables hafnia integration both into microelectronic packaging and local energy supply systems. Success of this project will enable development of resilient energy storage systems that would allow coping with the ever growing energy consumption. Successful project implementation will provide a basis for attracting new funding from federal agencies (NSF, DARPA, NREL, DOE) and from semiconductor companies involved in development of energy storage technologies (Intel, Fluence, Matsushita, Siemens Energy). Both PIs have a strong track record of industry collaboration (Intel, Seagate, Toshiba, Fujitsu), which demonstrates their technical expertise and ability to deliver impactful results.